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(54) Register marks.

(57) A register mark and a system for bringing a pair of register marks into alignment is disclosed. A first two-dimensional register mark (Fig. 1) comprises a plurality of dots of a first frequency, and a second two-dimensional register mark (Fig. 2) comprises a plurality of dots of a second, generally higher frequency. When the first and second register marks are overlaid, an interference pattern resulting from the difference in frequency is observed. The first and second register marks are in alignment when the interference pattern produces a maximum bright spot in the center of the register mark. A small relative movement of the first and second register marks results in a larger relative movement of center of the bright spot. The position of the bright spot indicates which direction and how much to move the second register mark in order to achieve image registration. It is preferred that the frequency of dots in each register mark is warped with distance from the center of the mark. The frequency of the dots of the second register mark is also warped with distance from the center, but overall has a generally higher frequency of dots as compared to the first register mark. In the resulting interference pattern the bright spot occurs unambiguously when the two register marks are in alignment. At misalignments of more than one dot width, the bright spot breaks up so that the overlaid register marks may serve as quick visual check of proper alignment. The register marks may be in a single dimension along a line.

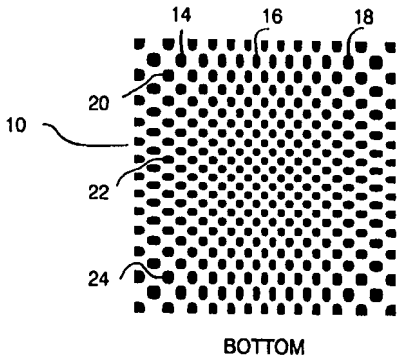

Fig. 1

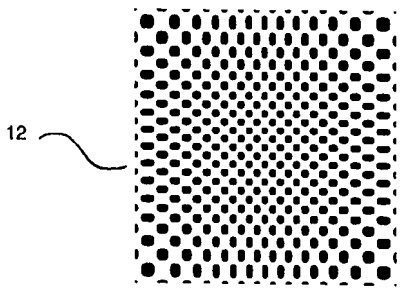

Fig. 2

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The present invention is concerned with field of register marks used for adjusting the relative position of two or more objects in order to bring the objects into alignment. The invention relates to a register mark arrangement and to a method and apparatus for aligning two objects using register marks. The invention further relates to monitoring the alignment of two objects such as layers using register marks. Particular, though not exclusive, applications of the invention are to the alignment of semiconductor masks and color printing.

In many manufacturing processes, it is often necessary to align two objects, such as two layers in which one layer will overlie the other. For example, in semiconductor manufacturing, successive masks which define the semiconductor structure are placed over the semiconductor substrate at various stages in the manufacturing process. Each successive mask must precisely align with the position of a previous mask on the semiconductor substrate.

As another example, in color printing, an original color image is scanned to separate the original image into several component colors, each of which component color will be separately printed in alignment with the layers above and below. Therefore, the color printing plates must be manufactured so that each of the separate color images are printed in precise alignment or registration with each other.

Specifically, an original input image is processed to produce four screened images: one for each of the printing inks of cyan, magenta, yellow and black. The four screened images are then used to burn printing plates needed in a four color printing reproduction process. In burning the plate, the image negative is affixed to a transparent acetate sheet with holes punched. The acetate sheet is then placed on the plate burning machine, which has metal tabs that fit into the holes in the acetate sheet. Each of the acetate sheets must have negatives at exactly the same position relative to the holes in order to insure that the plates have images in the same place. Accurate placement of the negatives on the acetate sheets is even more important if each plate is to be burned with more than one negative each.

To accurately place the negative on the acetate sheet, register marks are used. The first negative, typically corresponding to the black image plane, is placed on a light table that has metal tabs to fit the holes in the acetate sheet. The location of the first negative on the first acetate sheet is not too critical; a typical tolerance is on the order of 50 mils. The first negative placement determines the general location of the color image on the printed page.

The next step is to put another acetate sheet over the first sheet, and place a second negative, say the negative corresponding to the magenta image plane on the second acetate sheet in precise relation to the first negative on the first acetate sheet. To facilitate alignment, image negatives have register marks which are not part of the image and are later removed. The operator examines the register marks, usually with the aid of a magnifier. By close examination of the register marks, the operator determines the position of the second negative on the second acetate sheet for which the two register marks are exactly overlaid. The second acetate sheet carrying the aligned second image negative (magenta) is then removed. The process is repeated for a third acetate sheet and a third negative, say for cyan, and again for yellow. The acetate sheets are then used as indicated above to burn printing plates. The quality of color printing is dependent upon the accuracy of alignment of the four color images in the overall plate burning and printing process.

Automated processes for the automatic alignment of register marks are also known. The composite image of the two register marks is captured in a memory, the alignment error is measured, and one plate is moved in a direction so as to reduce the measured error. When the measured error is minimized, the register marks are aligned.

There are many known prior art register marks used to align two overlying transparent layers. One type of conventional register mark consists of crosshairs, i.e. a plus sign. This form of register mark has two disadvantages. First, a crosshairs register mark requires close examination, usually with the aid of a magnifier, to determine exact alignment. Second, when the two planes are not in good register, it is very difficult to determine from the non-aligned crosshair composite image which direction to move the top plane. Generally, trial and error movements indicate to the observer which direction to move the top plane. The need for close inspection and trial movements makes automated adjustment complex and expensive, in both the optical system and in the mechanical control system.

There will be described below a register mark arrangement in accordance with this invention and comprising a pair of register marks. There will also be described a system for bringing the pair of register marks into alignment. In one embodiment a first register mark comprises a plurality of dots of a first frequency, and a second register mark comprises a plurality of dots of a second, generally higher frequency. When the first and second register marks are overlaid, an interference pattern resulting from the difference in frequency is observed. The first and second register marks are in alignment when the interference pattern produces a maximum bright spot in the center of the register mark. A small relative movement of the first and second register marks results in a larger relative movement of center of the bright spot.

In an alternate embodiment of the present invention, the frequency of dots in each register mark is warped with distance from the center of the mark.

Specifically, the frequency of the dots in the first register mark is higher at the center than at the edges. The second register mark also contains a similar warping in frequency of the dots with distance from the center, but overall has a generally higher frequency of dots. The interference pattern resulting from an overlay of the two register marks results in a bright spot which occurs unambiguously when the two register marks are in alignment. At misalignments of more than one dot width, the bright spot breaks up so that the overlaid register marks may serve as quick visual check of proper alignment.

Register marks in accordance with the present invention may also be printed alongside the color image to check the final alignment of the overall printing process, or to monitor the operation of a high speed printing press. Furthermore, register marks in accordance with the present invention may be used in projection alignment systems where one register mark is printed or otherwise fixed onto a surface, and the other register mark is projected onto the first register mark, as for example in the manufacture of semiconductor integrated circuits. In general, as used herein, the term "print" shall mean either the deposition or removal of material so as to form an image on the surface of an object.

Aspects and features of the present invention are set out in the claims following this description. The invention and its practice will be more fully described with reference to the accompanying drawings, in which:

Figure 1 is an illustration of a bottom register mark in accordance with the present invention;

Figure 2 is an illustration of a top register mark in accordance with the present invention;

Figure 3 is an illustration of the pair of top and bottom register marks of Figs. 1 and 2 shown with the register marks in alignment;

Figure 4 is an illustration of the same pair of top and bottom register marks shown with the register marks out of alignment by 3 pixels to the right and 2 pixels down;

Figure 5 is an illustration of the same pair of top and bottom register marks shown with the register marks out of alignment by 13 pixels to the right and 5 pixels down;

Figures 6A-6K illustrates successive superimpositions of a pair of top and bottom register marks in accordance with the present invention, Figs. 6A showing the pair in alignment and each successive figure 6B-6K shown with top and bottom register marks out of alignment by an additional 2 pixels to the right;

Figure 7 is a block diagram of an automatic alignment system used in conjunction with a pair of register marks in accordance with the present invention; and

Figure 8 is a flow chart in accordance with the present invention for the computer program in the CPU of figure 7.

A register mark in accordance with the present invention is shown in figure 1, as a first register mark 10 comprising a plurality of dots of a first frequency. At least one horizontal line of dots includes dots 14, 16 and 18. The frequency at the center of the horizontal line is greatest at dot 16 near the center of the horizontal line, while the frequency of dots 14 and 18 decreases generally at distances away from the center. Similarly, register mark 10 includes at least one vertical line of dots such as dots 20, 22 and 24. The frequency at the center of the vertical line is greatest at dot 22 near the center of the horizontal line, while the frequency of dots 20 and 24 decreases generally at distances away from the center.

Figure 2 is a second register mark 12 comprising a plurality of dots. The arrangement of the second register mark is similar to the first register mark, but the entire pattern is of a generally higher frequency. For example, register mark 12 may have 5% higher frequency at all points, which results in a slightly smaller size for the second register mark as compared to the first register mark.

The use of these register marks as a pair will now be described. It is considered that these marks and others to be described are individually novel, as is the routine for generating them described below.

Figure 3 shows the first and second register marks in register. When the first and second register marks are in alignment, an interference pattern, produced by the sum and difference of the frequencies of the first and second register marks produces a bright spot in the center of the register mark. The bright spot results because the dots of the register mark tend to be coincident near the center, minimizing black while maximizing white area. Due to the frequency difference, the dots at a distance from the center tend to be more and more non-coincident, resulting in more and more black area. The net effect is a bright spot with a peak at coordinates defined by column 30 and row 32.

As the first and second register marks are moved out of alignment, the center of the bright spot moves away from the center in a direction so as to indicate the direction of the misalignment. Furthermore, if one mark is moved a small amount, the bright spot moves a much larger amount. The ratio is inversely proportional to the difference between the top and bottom register mark frequencies. By using a very small frequency difference between the two register marks, a magnification of 10 is easy to achieve. An example of an out of register condition is illustrated in figure 4 in which the top register mark is moved 3 pixels to the right and 2 pixels down. The center of the bright spot has moved to a coordinate location defined by column 34 and row 36, a much greater movement than 3 pixels right and 2 pixels down would indicate.

As the first and second register marks are moved even further out of alignment, the pattern becomes incoherent, i.e. there is no clearly defined bright spot. The latter situation is illustrated in figure 5 in which the top register mark is moved 13 pixels to the right and 5 pixels down. The patterns resulting from the use of pairs of register marks in accordance with the present invention are also known as moire patterns, which result from small differences in screen rulings and screen angles in the printing of color images.

Although dots shown in register marks 10 and 12 are of a generally rectangular shape, other dot shapes will also work. Furthermore, instead of frequency warping, one register mark may have a periodic pattern of a constant single frequency, and the second register mark may have a periodic pattern of a constant single, slightly higher frequency. A constant frequency pattern will produce an appropriate interference pattern and bright spot to indicate alignment. However, in the case of a constant frequency pattern, as the bright spot moves quickly to one side, another bright spot will move in from the other side. When the top and bottom register marks are offset by exactly one dot cycle, the bright spot appears exactly the same as when the top and bottom register marks are in perfect register. Due to the above described ambiguity, a constant frequency pattern cannot be used as a quick visual check of proper alignment, i.e. as a go/no go indicator. The warping of the dot pattern frequency with distance from the center of the register mark, avoids the ambiguity which could result from constant frequency register marks offset by one dot cycle.

An illustration of the interference patterns resulting from different relative horizontal positions of the top and bottom register marks is shown in figures 6A through 6K. In each successive figure, the top register mark is moved to the right, out of alignment by an additional 2 pixels as compared to the prior figure. The bright spot indicating alignment in figure 6A, moves further to the right in figures 6B, 6C, 6D and 6E, until substantially disappearing as shown in figure 6F. Figure 6F also shows another bright spot moving in from the other side. However, as shown in figures 6G, 6H, 6I, 6J and 6K the new bright spot breaks up before it moves to the center of the register mark. It is noted that two pairs of one dimensional register marks may also be used in lieu of the single pair of two dimensional register marks shown. In the latter case, one pair of register marks may provide a first bright spot in the form of a bright bar (instead of a circle) to indicate horizontal registration, while the other pair of register marks provides a second bright spot in the form of a bright bar to indicate vertical registration.

A particular advantage of the register mark of the present invention is that the position of the bright spot indicates which direction and how much to move the register mark in order to achieve image registration, a feature particularly useful in automatic alignment systems. Figure 7 is a block diagram of a system for automatically aligning two layers 50 and 56 using register marks 52 and 54 of the present invention. The system comprises an image capture apparatus 40, which may be a video camera or a line of photosensors, an image memory 42, a central processing unit (CPU) 44, and actuators 58 and 60 for moving layer 50 relative to layer 56.

In operation, layers 50 and 56 are placed in approximate alignment with register mark 52 overlying register mark 54. Camera 40 captures an image of the two register marks for storage in an image memory 42. CPU 44, responsive to the image memory 42 provides a vertical actuation signal on conductor 46 to vertical actuator 58, and a horizontal actuation signal on conductor 48 to horizontal actuator 60, until register marks 52 and 54 are in substantial alignment.

A flow chart for the program of CPU 44 is shown in figure 8. First an image of the two overlying register marks is captured at step 62. Thereafter, the peak of the bright spot is determined at step 64. Many techniques, such as upsampling and interpolation, are known to those skilled in the art for determining the position of a peak from a set of data points. After the peak is determined, the error between the peak of the bright spot and the center of the register mark is calculated at step 66. If the error is at a minimum, an indication of registration is made at step 72. However, if the test at 68 indicates an error, the drive actuators are effected at step 70 to bring the two register marks 52, 54 into alignment. A new image is captured at step 62, and the process repeats.

Register marks are also often printed alongside the completed color image in order to check the overall printing system accuracy. One pair of register marks may be used for each of cyan, magenta and yellow, the register mark for each color being printed over the register mark for black. A glance at the pairs of printed register marks will tell whether each of the color planes of the final image has been accurately aligned.

In the case of a moving printed image, as in a high speed printing press, the printed register marks may be used to monitor the accuracy of the overall printing system. The image of the register marks may be captured by the use of a line sensor of photosensitive elements to scan the image of the register marks as the printed register marks move past the line sensor. The image processor detects misalignments by the position of the bright spot and initiates appropriate adjustments or alerts the operator to the status of the error condition. A register mark of the present invention does not require high intensity flash illumination systems or high resolution optics, in order to accurately determine alignment error from the register marks, thereby saving considerable cost and complexity in

the design of automatic alignment and monitoring systems.

Finally, register marks in accordance with the present invention may be used in projection alignment systems to align integrated circuit masks used in semiconductor manufacturing. In the latter case, the first register mark may be etched or deposited on the substrate, and the other register mark projected onto the first register mark. The finished semiconductor wafer may contain one or more pairs of overlying register marks so that an observer may determine at a glance whether each of the semiconductor masks of the final integrated circuit have been accurately aligned.

A program written in QuickBASIC 4.5 to generate a register mark is given below:

```
SUB MakeReg (z)
    DIM zz(200)
    FOR i = 0 TO 199
        za = i - 100
        zb = za * .01
        zc = zb - .2 * zb ^ 3
        zd = COS(zc * 50 * z)
        zz(i) = zd
    NEXT
    FOR j = 0 TO 199
      zj = zz(j)
      FOR i = 0 TO 199
          IF zz(i) * zj > -.25 THEN PSET (i,
j)
      NEXT
    NEXT
END SUB
```

The z parameter is preferably 1.0 for the first (black plane) register mark 10, and 1.05 for the other register mark 12, corresponding to a 5 percent increase in frequency between the first and second register marks. The above program generates a register mark 200 x 200 pixels. The -.25 figure controls the size of the dots in the register mark pattern (i.e. the percent gray, not the frequency), and may be changed for different dot sizes, as desired.

Claims

1. A register mark arrangement comprising:
   a first register mark including a first plurality of dots at a first frequency; and
   a second register mark including a second plurality of dots at a second frequency;
   wherein said second register mark is disposed in overlaid relation to said first register mark to thereby produce an interference pattern indicative of the registration of said first and second register marks.

2. A register mark arrangement in accordance with claim 1, wherein the frequency of dots in each register mark varies with distance from the center of each said register mark.

3. A register mark in accordance with claim 2, wherein the frequency of dots in each register mark generally decreases with distance from the center of each said register mark.

4. A register mark in accordance with claim 2, wherein the frequency of dots in each register mark generally increases with distance from the center of each said register mark.

5. A register mark in accordance with claim 1, 2 or 3 wherein said first register mark is printed, and second register mark is printed over said first register mark.

6. A register mark in accordance with claim 1, 2 or 3 wherein said first register mark is printed, and second register mark is projected over said first register mark.

7. A register mark arrangement comprising:
   a first register mark including a first plurality of dots at a first frequency arranged in a two dimensional array; and
   a second register mark including a second plurality of dots at a second frequency arranged in two dimensional array;
   wherein said second register mark is disposed in overlaid relation to said first register mark to thereby produce an interference pattern indicative of the registration of said first and second register marks.

8. A register mark arrangement in accordance with claim 7, wherein the frequency of dots in each register mark varies with radial distance from the center of each said register mark.

9. A register mark in accordance with claim 8, wherein the frequency of dots in each register mark generally decreases with radial distance from the center of each said register mark.

10. A register mark in accordance with claim 8, wherein the frequency of dots in each register mark generally increases with distance from the center of each said register mark.

11. A register mark in accordance with claim 7, 8 or 9, wherein said first register mark is printed, and second register mark is printed over said first register mark.

12. A register mark in accordance with claim 7, 8 or

9 wherein said first register mark is printed, and second register mark is projected over said first register mark.

13. A method for aligning first and second objects, wherein said first and second objects are coupled to respective first and second register marks, said first register mark including a first plurality of dots at a first frequency and said second register mark including a second plurality of dots at a second frequency, said method comprising:

positioning at least one of said first and second objects so that said second register mark is disposed in overlaid relation to said first register mark, thereby producing a bright spot indicative of the registration of said first and second register marks;

detecting the position of said bright spot; and moving said one of said first and second objects to reposition said bright spot towards the center of said one of said first and second register marks.

14. A method in accordance with claim 13, wherein the frequency of dots in each register mark varies with distance from the center of each said register mark.

15. A method in accordance with claim 14, wherein the frequency of dots in each register mark generally decreases with distance from the center of each said register mark.

16. A register mark in accordance with claim 14, wherein the frequency of dots in each register mark generally increases with distance from the center of each said register mark.

17. A method in accordance with claim 13, 14, 15 or 16 wherein said first register mark is printed, and second register mark is printed over said first register mark.

18. A method in accordance with claim 13, 14, 15 or 16 wherein said first register mark is printed, and second register mark is projected over said first register mark.

19. A method in accordance with claim 13, 14, 15 or 16 wherein said first object represents a first color plane of a printed color image and said second object represents a second color plane of said printed color image.

20. A method in accordance with claim 13, 14, 15 or 16 wherein said first object is a first semiconductor mask of an integrated circuit, and said second object is a second semiconductor mask of said integrated circuit.

21. A method for monitoring the alignment of first and second layers, wherein said first and second layers have a predetermined relation to respective first and second register marks, said first register mark including a first plurality of dots at a first frequency and said second register mark including a second plurality of dots at a second frequency, said method comprising:

positioning at least one of said first and second layers so that said second register mark is disposed in overlaid relation to said first register mark, thereby producing a bright spot indicative of the registration of said first and second register marks;

detecting the position of said bright spot; and providing an indication representative of the position of said bright spot relative to the center of said one of said first and second register marks.

22. A method in accordance with claim 21, wherein the frequency of dots in each register mark varies with distance from the center of each said register mark.

23. A method in accordance with claim 22, wherein the frequency of dots in each register mark generally decreases with distance from the center of each said register mark.

24. A method in accordance with claim 21, 22 or 23, wherein said first register mark is printed, and second register mark is printed over said first register mark.

25. A method in accordance with claim 21, 22 or 23, wherein said first layer represents a first color plane of a printed color image and said second layer represents a second color plane of said printed color image.

26. A method in accordance with claim 21, 22 or 23 wherein said first layer is a first semiconductor mask of an integrated circuit, and said second layer is a second semiconductor mask of said integrated circuit.

27. A method in accordance with any one of claims 21 to 26, wherein said step of detecting the position of said bright spot indicative of the registration of said first and second register marks includes

sensing one line of said first and second register marks; and

moving said first and second register marks thereby forming a two dimensional image

of said first and second register marks.

28. An apparatus for aligning first and second objects, wherein said first and second objects are coupled to respective first and second register marks, said first register mark including a first plurality of dots at a first frequency and said second register mark including a second plurality of dots at a second frequency, said method comprising:

means for positioning at least one of said first and second objects so that said second register mark is disposed in overlaid relation to said first register mark, thereby producing a bright spot indicative of the registration of said first and second register marks;

means for detecting the position of said bright spot; and

means for moving said one of said first and second objects to reposition said bright spot towards the center of said one of said first and second register marks.

29. An apparatus in accordance with claim 28, wherein the frequency of dots in each register mark varies with distance from the center of each said register mark.

30. An apparatus in accordance with claim 29, wherein the frequency of dots in each register mark generally decreases with distance from the center of each said register mark.

31. An apparatus in accordance with claim 29, wherein the frequency of dots in each register mark generally increases with distance from the center of each said register mark.

32. An apparatus in accordance with claim 28, 29, 30 or 31, wherein said first register mark is printed, and second register mark is printed over said first register mark.

33. An apparatus in accordance with claim 28, 29, 30 or 31, wherein said first register mark is printed, and second register mark is projected over said first register mark.

34. An apparatus in accordance with claim 28, 29, 30 or 31, wherein said first object represents a first color plane of a printed color image and said second object represents a second color plane of said printed color image.

35. An apparatus in accordance with claim 28, 29, 30 or 31, wherein said first object is a first semiconductor mask of an integrated circuit, and said second object is a second semiconductor mask of said integrated circuit.

36. An apparatus for monitoring the alignment of first and second layers, wherein said first and second layers have a predetermined relation to respective first and second register marks, said first register mark including a first plurality of dots at a first frequency and said second register mark including a second plurality of dots at a second frequency, said method comprising:

means for positioning at least one of said first and second layers so that said second register mark is disposed in overlaid relation to said first register mark, thereby producing a bright spot indicative of the registration of said first and second register marks;

means for detecting the position of said bright spot; and

means for providing an indication representative of the position of said bright spot relative to the center of said one of said first and second register marks.

37. An apparatus in accordance with claim 36, wherein the frequency of dots in each register mark varies with distance from the center of each said register mark.

38. An apparatus in accordance with claim 37, wherein the frequency of dots in each register mark generally decreases with distance from the center of each said register mark.

39. An apparatus in accordance with claim 36, 37 or 38, wherein said first register mark is printed, and second register mark is printed over said first register mark.

40. An apparatus in accordance with claim 36, 37 or 38 wherein said first layer represents a first color plane of a printed color image and said second layer represents a second color plane of said printed color image.

41. An apparatus in accordance with claim 36, 37 or 38 wherein said first layer is a first semiconductor mask of an integrated circuit, and said second layer is a second semiconductor mask of said integrated circuit.

42. An apparatus in accordance with claim 36, 37 or 38 wherein said means for detecting the position of said bright spot indicative of the registration of said first and second register marks includes

means for sensing one line of said first and second register marks; and

means for moving said first and second register marks thereby forming a two dimensional image of said first and second register marks.

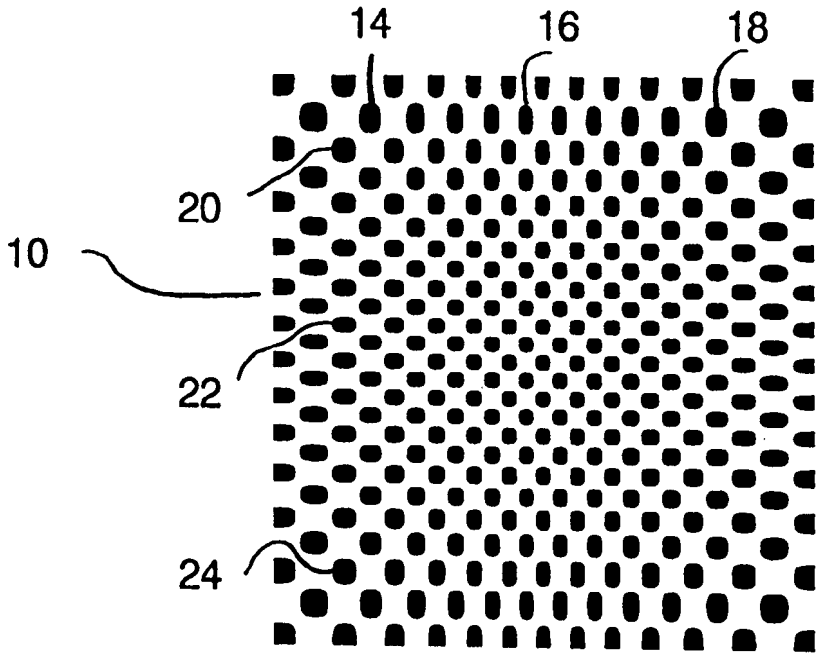

Fig. 1

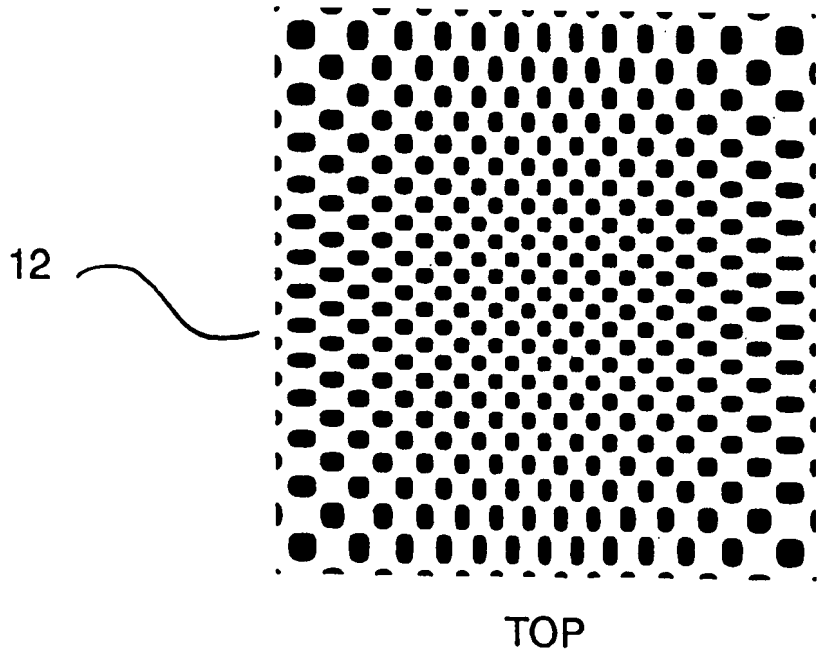

Fig. 2

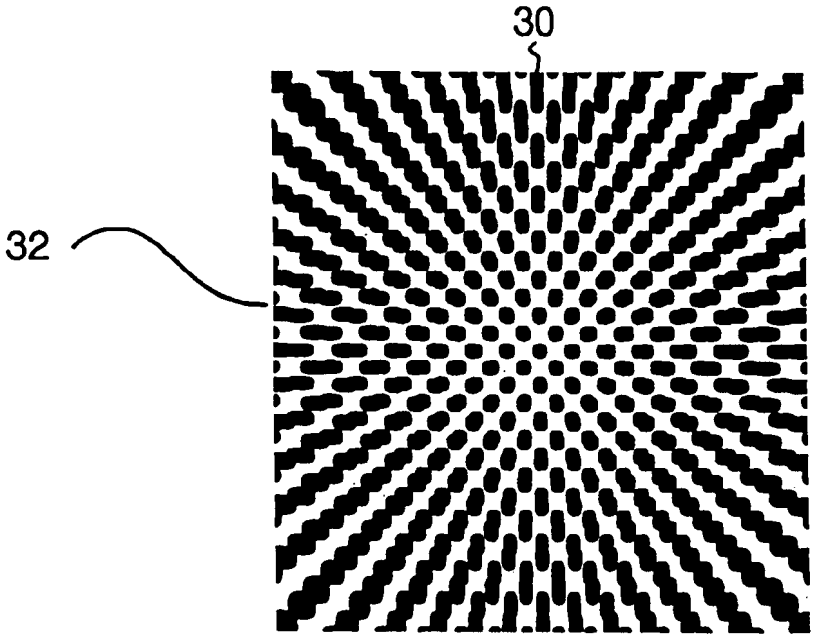

Fig. 3

IN REGISTER

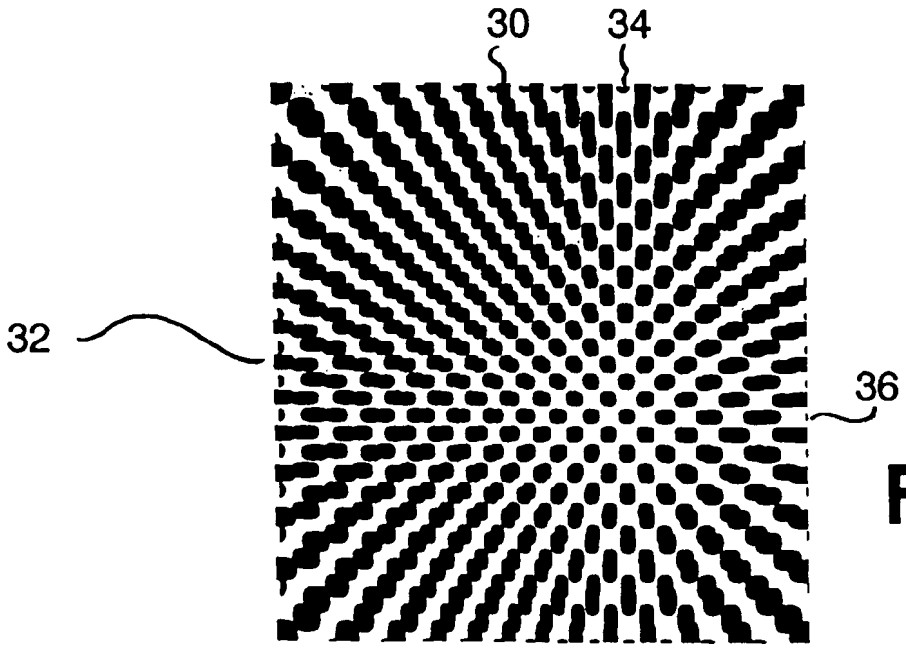

Fig. 4

OUT OF REGISTER
3 PIXELS RIGHT, 2 PIXELS DOWN

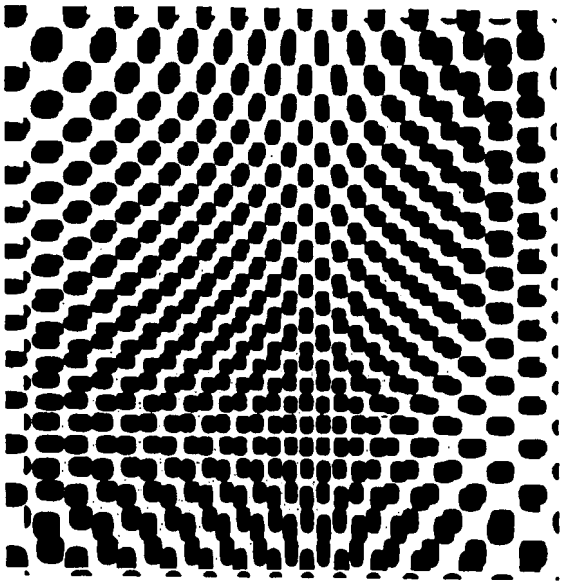

Fig. 5

OUT OF REGISTER
13 PIXELS RIGHT, 5 PIXELS DOWN

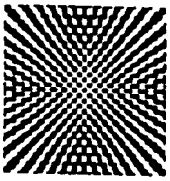

Fig. 6A
IN REGISTER

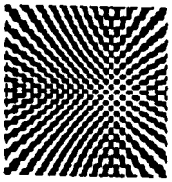

Fig. 6B
+2 PIXELS

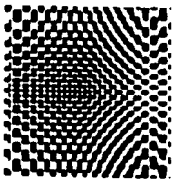

Fig. 6C
+4 PIXELS

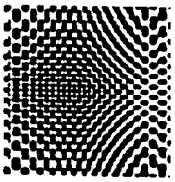

Fig. 6D
+6 PIXELS

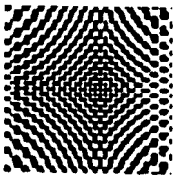

Fig. 6E
+8 PIXELS

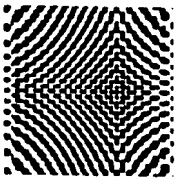

Fig. 6F
+10 PIXELS

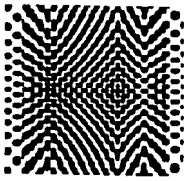

Fig. 6G
+12 PIXELS

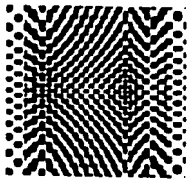

Fig. 6H
+14 PIXELS

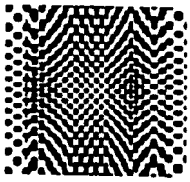

Fig. 6I
+16 PIXELS

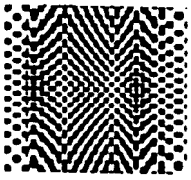

Fig. 6J
+18 PIXELS

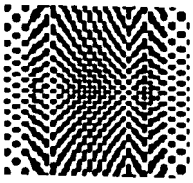

Fig. 6K
+20 PIXELS

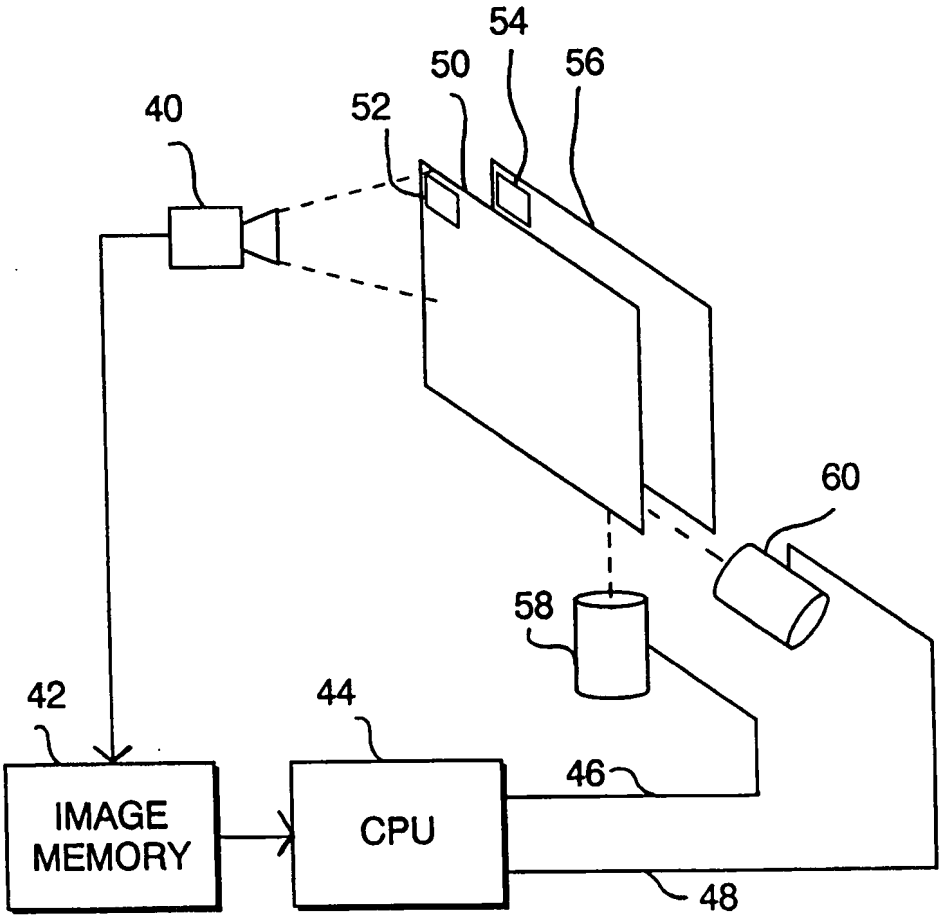

Fig. 7

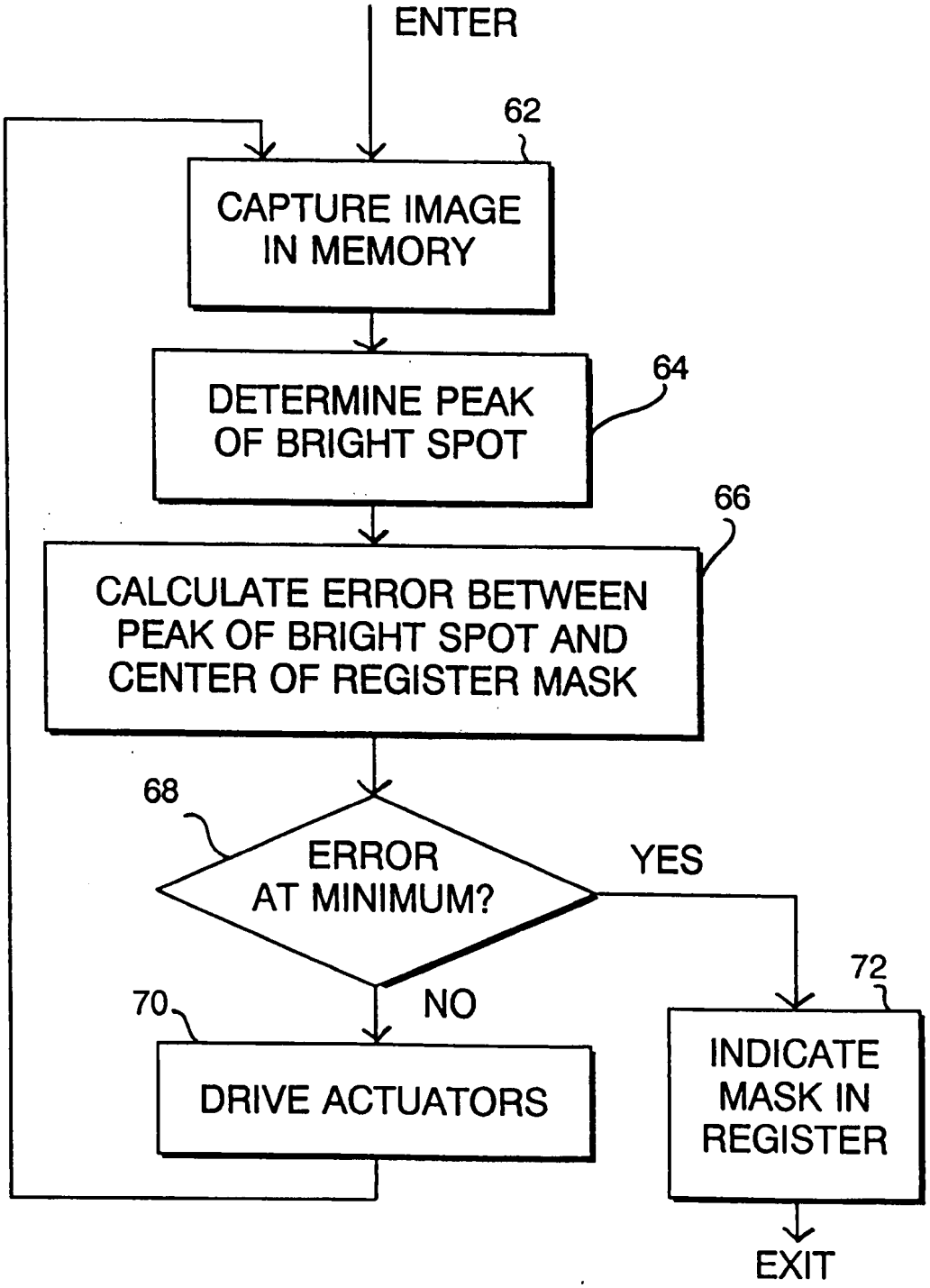
ENTER
62
CAPTURE IMAGE IN MEMORY
64
DETERMINE PEAK OF BRIGHT SPOT
66
CALCULATE ERROR BETWEEN PEAK OF BRIGHT SPOT AND CENTER OF REGISTER MASK
68
ERROR AT MINIMUM?
YES
NO
70
DRIVE ACTUATORS
72
INDICATE MASK IN REGISTER
EXIT

Fig. 8

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 92 30 8632

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	IBM TECHNICAL DISCLOSURE BULLETIN. vol. 32, no. 10B, March 1990, NEW YORK US pages 214 - 217 , XP97868 'INTERFEROMETRIC METHOD OF CHECKING THE OVERLAY ACCURACY IN PHOTOLITHOGRAPHIC EXPOSURE PROCESSES'	1,5,7,11	G03F9/00
Y	* the whole document *	6,12	
A		13,21, 28,36	

Y	WO-A-8 604 158 (AMERICAN TELEPHONE & TELEGRAPH COMPANY) * abstract *	6,12	

A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 150 (E-742)12 April 1989 & JP-A-63 311 735 (OKI ELECTRIC IND CO LTD) 20 December 1988 * abstract *	1,7,13, 21,28,36	

A	PATENT ABSTRACTS OF JAPAN vol. 8, no. 196 (P-299)8 September 1984 & JP-A-59 083 167 (OKI DENKI KOGYO KK) 14 May 1984 * abstract *	1,7,13, 21,28,36	TECHNICAL FIELDS SEARCHED (Int. Cl.5) G03F

A	US-A-4 704 033 (FAY ET AL.) * column 2, line 36 - line 52; figures *	1,7,13 21,28,36	

A	GB-A-2 183 364 (THE GENERAL ELECTRIC COMPANY PLC) * page 1, line 96 - page 2, line 24 * * figures 1-4 *	2,8,14, 22,29,37	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22 DECEMBER 1992	HERYET C.D.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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Ausrichtmarken

Marques d'alignement

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(56) References cited:
WO-A-86/04158 **GB-A- 2 183 364**
US-A- 4 704 033

- **IBM TECHNICAL DISCLOSURE BULLETIN. vol. 32, no. 10B, March 1990, NEW YORK US pages 214 - 217 , XP97868 'INTERFEROMETRIC METHOD OF CHECKING THE OVERLAY ACCURACY IN PHOTOLITHOGRAPHIC EXPOSURE PROCESSES'**
- **PATENT ABSTRACTS OF JAPAN vol. 13, no. 150 (E-742)12 April 1989**
- **PATENT ABSTRACTS OF JAPAN vol. 8, no. 196 (P-299)8 September 1984**

EP 0 534 720 B1

Description

The present invention is concerned with field of register marks used for adjusting the relative position of two or more objects in order to bring the objects into alignment. The invention relates to a register mark arrangement and to a method and apparatus for aligning two objects using register marks. The invention further relates to monitoring the alignment of two objects such as layers using register marks. Particular, though not exclusive, applications of the invention are to the alignment of semiconductor masks and color printing.

In many manufacturing processes, it is often necessary to align two objects, such as two layers in which one layer will overlie the other. For example, in semiconductor manufacturing, successive masks which define the semiconductor structure are placed over the semiconductor substrate at various stages in the manufacturing process. Each successive mask must precisely align with the position of a previous mask on the semiconductor substrate.

As another example, in color printing, an original color image is scanned to separate the original image into several component colors, each of which component color will be separately printed in alignment with the layers above and below. Therefore, the color printing plates must be manufactured so that each of the separate color images are printed in precise alignment or registration with each other.

Specifically, an original input image is processed to produce four screened images: one for each of the printing inks of cyan, magenta, yellow and black. The four screened images are then used to burn printing plates needed in a four color printing reproduction process. In burning the plate, the image negative is affixed to a transparent acetate sheet with holes punched. The acetate sheet is then placed on the plate burning machine, which has metal tabs that fit into the holes in the acetate sheet. Each of the acetate sheets must have negatives at exactly the same position relative to the holes in order to insure that the plates have images in the same place. Accurate placement of the negatives on the acetate sheets is even more important if each plate is to be burned with more than one negative each.

To accurately place the negative on the acetate sheet, register marks are used. The first negative, typically corresponding to the black image plane, is placed on a light table that has metal tabs to fit the holes in the acetate sheet. The location of the first negative on the first acetate sheet is not too critical; a typical tolerance is on the order of 0,13 mm (50 mils). The first negative placement determines the general location of the color image on the printed page.

The next step is to put another acetate sheet over the first sheet, and place a second negative, say the negative corresponding to the magenta image plane on the second acetate sheet in precise relation to the first negative on the first acetate sheet. To facilitate alignment, image negatives have register marks which are not part of the image and are later removed. The operator examines the register marks, usually with the aid of a magnifier. By close examination of the register marks, the operator determines the position of the second negative on the second acetate sheet for which the two register marks are exactly overlaid. The second acetate sheet carrying the aligned second image negative (magenta) is then removed. The process is repeated for a third acetate sheet and a third negative, say for cyan, and again for yellow. The acetate sheets are then used as indicated above to burn printing plates. The quality of color printing is dependent upon the accuracy of alignment of the four color images in the overall plate burning and printing process.

Automated processes for the automatic alignment of register marks are also known. The composite image of the two register marks is captured in a memory, the alignment error is measured, and one plate is moved in a direction so as to reduce the measured error. When the measured error is minimized, the register marks are aligned.

There are many known prior art register marks used to align two overlying transparent layers. One type of conventional register mark consists of crosshairs, i.e. a plus sign. This form of register mark has two disadvantages. First, a crosshairs register mark requires close examination, usually with the aid of a magnifier, to determine exact alignment. Second, when the two planes are not in good register, it is very difficult to determine from the non-aligned crosshair composite image which direction to move the top plane. Generally, trial and error movements indicate to the observer which direction to move the top plane. The need for close inspection and trial movements makes automated adjustment complex and expensive, in both the optical system and in the mechanical control system.

It is known to provide register marks which act as diffraction gratings for light, such as a laser beam, impinging on them. The alignment of the register marks is determined by monitoring the respective patterns of the diffracted light. An example of this technique is disclosed in "Interferometric Method of Checking the Overlay Accuracy in Photolithographic Exposure Processes, IBM Technical Disclosure Bulletin, Vol. 32, No. 10B, March 1990. The arrangement there described monitors alignment along only one axis. Another interferometric method based on diffraction is disclosed in U.S. patent 4 704 033 to Fay et al.

GB-A-2 183 364 discloses a register mark arrangement of the kind comprising:

a first register mark including a plurality of elements, the frequency of the spacial arrangement of which changes across the first register mark, and a second register mark including a second plurality of elements, the frequency of the spacial arrangement of which changes across the second register mark.

More specifically GB-A-2 183 364 discloses an alignment method involving detection of the interference (Moire) pattern between the two register marks when they are overlaid. Furthermore the marks are overlaid such that one is

a mirror image of the other. The two register marks are identical and thus their elements have the same spacial frequency variation. This variation is in a single sense, that is from higher to lower along the axis of alignment. This is a chirp grating. The elements themselves are stripes transverse to and angled with respect to the axis of alignment. The interference pattern at the point of alignment is a straight band extending along this axis. Misalignment of the axis distorts the straight band by introducing a curvature. The principles of this technique are used in an adaptation for detection of alignment along two axes. Correct alignment is indicated by a cross having straight sides. Curvature of the sides results from misalignment.

The present invention provides a register mark arrangement of the kind set forth above which is characterized in that:

the elements of said first and second pluralities of elements comprise dots,
the spacial frequency of each of said first and second pluralities of dots varies in the same sense with distance from the centre of said first and second register marks respectively,
the spacial frequency of the dots of said second register mark is greater than the spacial frequency of the dots of said first register mark at corresponding areas of the first and second register marks, and
said first and second pluralities of dots being arranged and said spacial frequencies chosen to produce an interference pattern including a bright spot at the centre of said register marks, when said register marks are disposed in overlaid relation, which is indicative of the alignment of said first and second register marks.

The variation of spacial frequency away from the centres of the register marks is also referred to as frequency warping.

The preferred register mark arrangement is a two-dimensional array of dots, the respective spacial frequencies of each plurality decreasing with radial distance from the respective centres of the register marks.

The bright spot in the interference pattern produced in the register mark arrangement according to the invention occurs unambiguously when the two register marks are aligned. Furthermore at small displacements (explained later) from the aligned position, the bright spot moves and the detection of the position of the peak of the bright spot with respect to the centre of one register mark is usable to calculate an error which is a measure of the misalignment in both direction and amount and which may be used to control relative movement between the two register marks to bring them into alignment. By selecting the difference of the spacial frequencies of the dots of the two register marks, the displacement of the bright spot may be magnified with respect to the displacement of the register marks from alignment. A small relative movement of the first and second register marks results in a larger relative movement of the bright spot.

The invention also provides a method of monitoring the alignment of and aligning first and second objects which carry first and second register marks respectively for locating in overlaid relationship to determine the alignment of the first and second objects as described in the claims 11 and 19. The first and second register marks provide a register mark arrangement in accordance with the invention.

The invention further provides apparatus for monitoring the alignment of first and second objects carrying first and second register marks respectively, which register marks are located in overlaid relation; and apparatus for aligning such first and second objects as described in claims 21 and 22. In each case the first and second register marks provide a register mark arrangement in accordance with the invention.

Applications of the method and apparatus of the invention are in aligning a semiconductor substrate and a mask or aligning two masks in the production of integrated circuits; and in colour printing, for example the production of printing plates from colour negatives relating to an image.

Register marks having the characteristics defined above in accordance with the present invention may also be printed alongside the color image to check the final alignment of the overall printing process, or to monitor the operation of a high speed printing press. Furthermore, such register marks may be used in projection alignment systems where one register mark is printed or otherwise fixed onto a surface, and the other register mark is projected onto the first register mark, as for example in the manufacture of semiconductor integrated circuits. In general, as used herein, the term "print" shall mean either the deposition or removal of material so as to form an image on the surface of an object.

The invention and its practice will be more fully described with reference to the accompanying drawings, in which:

Figure 1 is an illustration of a bottom register mark for a register mark arrangement in accordance with the present invention;
Figure 2 is an illustration of a complementary top register mark for the register mark arrangement;
Figure 3 is an illustration of the pair of top and bottom register marks of Figs. 1 and 2 shown with the register marks in alignment;
Figure 4 is an illustration of the same pair of top and bottom register marks shown with the register marks out of alignment by 3 pixels to the right and 2 pixels down;

Figure 5 is an illustration of the same pair of top and bottom register marks shown with the register marks out of alignment by 13 pixels to the right and 5 pixels down;

Figures 6A-6K illustrates successive superimpositions of a pair of top and bottom register marks, Figs. 6A showing the pair in alignment and each successive figure 6B-6K shown with top and bottom register marks out of alignment by an additional 2 pixels to the right;

Figure 7 is a block diagram of an automatic alignment system used in conjunction with a pair of register marks in accordance with the present invention; and

Figure 8 is a flow chart for the computer program in the CPU of figure 7.

A first register mark 10 of a register mark arrangement in accordance with the present invention is shown in figure 1, as comprising a plurality of dots of a first frequency. At least one horizontal line of dots includes dots 14, 16 and 18. The frequency at the center of the horizontal line is greatest at dot 16 near the center of the horizontal line, while the frequency of dots 14 and 18 decreases generally at distances away from the center. Similarly, register mark 10 includes at least one vertical line of dots such as dots 20, 22 and 24. The frequency at the center of the vertical line is greatest at dot 22 near the center of the horizontal line, while the frequency of dots 20 and 24 decreases generally at distances away from the center.

Figure 2 is a second register mark 12 of the register mark arrangement comprising a plurality of dots. The arrangement of the second register mark is similar to the first register mark, but the entire pattern is of a generally higher frequency. For example, register mark 12 may have 5% higher frequency at all points, which results in a slightly smaller size for the second register mark as compared to the first register mark.

The use of these register marks as a pair will now be described. It is considered that these marks and others to be described are individually novel, as is the routine for generating them described below.

Figure 3 shows the first and second register marks in register. When the first and second register marks are in alignment, an interference pattern, produced by the sum and difference of the frequencies of the first and second register marks produces a bright spot in the center of the register mark. The bright spot results because the dots of the register mark tend to be coincident near the center, minimizing black while maximizing white area. Due to the frequency difference, the dots at a distance from the center tend to be more and more non-coincident, resulting in more and more black area. The net effect is a bright spot with a peak at coordinates defined by column 30 and row 32.

As the first and second register marks are moved out of alignment, the center of the bright spot moves away from the center in a direction so as to indicate the direction of the misalignment. Furthermore, if one mark is moved a small amount, the bright spot moves a much larger amount. The ratio is inversely proportional to the difference between the top and bottom register mark frequencies. By using a very small frequency difference between the two register marks, a magnification of 10 is easy to achieve. An example of an out of register condition is illustrated in figure 4 in which the top register mark is moved 3 pixels to the right and 2 pixels down. The center of the bright spot has moved to a coordinate location defined by column 34 and row 36, a much greater movement than 3 pixels right and 2 pixels down would indicate.

As the first and second register marks-are moved even further out of alignment, by more than one dot width, the pattern becomes incoherent, i.e. there is no clearly defined bright spot. The latter situation is illustrated in figure 5 in which the top register mark is moved 13 pixels to the right and 5 pixels down. The patterns resulting from the use of pairs of register marks in accordance with the present invention are also known as moire patterns, which result from small differences in screen rulings and screen angles in the printing of color images.

Although dots shown in register marks 10 and 12 are of a generally rectangular shape, other dot shapes will also work. If, instead of frequency warping, one register mark has a periodic pattern of a constant single frequency, and the second register mark has a periodic pattern of a constant single, slightly higher frequency, the constant frequency pattern will produce an appropriate interference pattern and bright spot to indicate alignment. However, in the case of a constant frequency pattern, as the bright spot moves quickly to one side, another bright spot will move in from the other side. When the top and bottom register marks are offset by exactly one dot cycle, the bright spot appears exactly the same as when the top and bottom register marks are in perfect register. Due to the above described ambiguity, a constant frequency pattern cannot be used as a quick visual check of proper alignment, i.e. as a go/no go indicator. The warping of the dot pattern frequency with distance from the center of the register mark, avoids the ambiguity which could result from constant frequency register marks offset by one dot cycle.

An illustration of the interference patterns resulting from different relative horizontal positions of the top and bottom register marks is shown in figures 6A through 6K. In each successive figure, the top register mark is moved to the right, out of alignment by an additional 2 pixels as compared to the prior figure. The bright spot indicating alignment in figure 6A, moves further to the right in figures 6B, 6C, 6D and 6E, until substantially disappearing as shown in figure 6F. Figure 6F also shows another bright spot moving in from the other side. However, as shown in figures 6G, 6H, 6I, 6J and 6K the new bright spot breaks up before it moves to the center of the register mark. It is noted that two pairs of one dimensional register marks may also be used in lieu of the single pair of two dimensional register marks shown.

In the latter case, one pair of register marks may provide a first bright spot in the form of a bright bar (instead of a circle) to indicate horizontal registration, while the other pair of register marks provides a second bright spot in the form of a bright bar to indicate vertical registration.

A particular advantage of the register mark of the present invention is that the position of the bright spot indicates which direction and how much to move the register mark in order to achieve image registration, a feature particularly useful in automatic alignment systems. Figure 7 is a block diagram of a system for automatically aligning two layers 50 and 56 using register marks 52 and 54 of the present invention. The system comprises an image capture apparatus 40, which may be a video camera or a line of photosensors, an image memory 42, a central processing unit (CPU) 44, and actuators 58 and 60 for moving layer 50 relative to layer 56.

In operation, layers 50 and 56 are placed in approximate alignment with register mark 52 overlying register mark 54. Camera 40 captures an image of the two register marks for storage in an image memory 42. CPU 44, responsive to the image memory 42 provides a vertical actuation signal on conductor 46 to vertical actuator 58, and a horizontal actuation signal on conductor 48 to horizontal actuator 60, until register marks 52 and 54 are in substantial alignment.

A flow chart for the program of CPU 44 is shown in figure 8. First an image of the two overlying register marks is captured at step 62. Thereafter, the peak of the bright spot is determined at step 64. Many techniques, such as up-sampling and interpolation, are known to those skilled in the art for determining the position of a peak from a set of data points. After the peak is determined, the error between the peak of the bright spot and the center of the register mark is calculated at step 66. If the error is at a minimum, an indication of registration is made at step 72. However, if the test at 68 indicates an error, the drive actuators are effected at step 70 to bring the two register marks 52, 54 into alignment. A new image is captured at step 62, and the process repeats.

Register marks are also often printed alongside the completed color image in order to check the overall printing system accuracy. One pair of register marks may be used for each of cyan, magenta and yellow, the register mark for each color being printed over the register mark for black. A glance at the pairs of printed register marks will tell whether each of the color planes of the final image has been accurately aligned.

In the case of a moving printed image, as in a high speed printing press, the printed register marks may be used to monitor the accuracy of the overall printing system. The image of the register marks may be captured by the use of a line sensor of photosensitive elements to scan the image of the register marks as the printed register marks move past the line sensor. The image processor detects misalignments by the position of the bright spot and initiates appropriate adjustments or alerts the operator to the status of the error condition. A register mark of the present invention does not require high intensity flash illumination systems or high resolution optics, in order to accurately determine alignment error from the register marks, thereby saving considerable cost and complexity in the design of automatic alignment and monitoring systems.

Finally, register marks for use in accordance with the present invention may be used in projection alignment systems to align integrated circuit masks used in semiconductor manufacturing. In the latter case, the first register mark may be etched or deposited on the substrate, and the other register mark projected onto the first register mark. The finished semiconductor wafer may contain one or more pairs of overlying register marks so that an observer may determine at a glance whether each of the semiconductor masks of the final integrated circuit have been accurately aligned.

A program written in QuickBASIC 4.5 to generate a register mark is given below:

```
SUB MakeReg (z)
     DIM zz(200)
     FOR i = 0 TO 199
          za = i - 100
          zb = za * .01
          zc = zb - .2 * zb ^ 3
          zd = COS(zc * 50 * z)
          zz(i) = zd
     NEXT
     FOR j = 0 TO 199
        zj = zz(j)
        FOR i = 0 TO 199
           IF zz(i) * zj > -.25 THEN PSET (i, j)
        NEXT
     NEXT
END SUB
```

The z parameter is preferably 1.0 for the first (black plane) register mark 10, and 1.05 for the other register mark 12, corresponding to a 5 percent increase in frequency between the first and second register marks. The above program generates a register mark 200 x 200 pixels. The -.25 figure controls the size of the dots in the register mark pattern (i. e. the percent gray, not the frequency), and may be changed for different dot sizes, as desired.

Claims

1. A register mark arrangement comprising:

   a first register mark (10) including a first plurality of elements, the frequency of the spacial arrangement of which varies across the first register mark (10), and
   a second register mark (12) including a second plurality of elements, the frequency of the spacial arrangement of which varies across the second register mark (12),

   characterized in that:

   the elements of said first and second pluralities of elements comprise dots,
   the spacial frequency of each of said first and second pluralities of dots varies in the same sense with distance from the centre of said first and second register marks respectively,
   the spacial frequency of the dots of said second register mark is greater than the spacial frequency of the dots of said first register mark at corresponding areas of the first and second register marks, and
   said first and second pluralities of dots being arranged and said spacial frequencies chosen to produce an interference pattern including a bright spot at the centre of said register marks, when said register marks are disposed in overlaid relation, which is indicative of the alignment of said first and second register marks.

2. A register mark arrangement according to Claim 1 in which said first and second pluralities of dots each comprises at least one line of dots in each of two orthogonal directions.

3. A register mark arrangement according to Claim 1 in which each of said first and second pluralities of dots is a two-dimensional array of dots in which the spacial frequency of the dots decreases in opposite directions from the centre of the respective first and second register marks.

4. A register mark arrangement according to Claim 1 in which each of said first and second pluralities of dots is a two-dimensional array of dots in which the spacial frequency of the dots increases in opposite directions from the centre of the respective first and second register marks.

5. A register mark arrangement as claimed in Claim 1 in which each of said first and second pluralities of dots is a two-dimensional array of dots in which the spacial frequency of the dots is a function of the radial distance from the centre of the register mark.

6. A register mark arrangement as claimed in Claim 5 in which in each of said first and second pluralities of dots the spacial frequency decreases with radial distance from the centre of the first and second register marks respectively.

7. A register mark arrangement as claimed in Claim 5 in which in each of said first and second pluralities of dots the spacial frequency increases with radial distance from the centre of the first and second register marks respectively.

8. A register mark arrangement as claimed in any preceding claim in which the spacial frequency of the dots of said second plurality is about 5% greater than the spacial frequency of the dots of said first plurality at corresponding areas of said first and second register marks.

9. A register mark arrangement as claimed in any one of Claims 1 to 8 in which said first register mark is printed and said second register mark is projected thereon.

10. A register mark arrangement as claimed in any preceding claim in which said first register mark is printed and said second register mark is printed thereover.

11. A method of aligning first and second objects in which said first and second objects carry first and second register

marks respectively for locating in overlaid relation to determine the alignment of said first and second objects, characterized in that:

said first and second register marks provide a register mark arrangement which is in accordance with any one of claims 1 to 9, and wherein relative movement is effected between said first and second objects to bring the interference pattern between said first and second register marks to a condition exhibiting said bright spot at the centre of the register marks indicative of alignment thereof.

12. A method as claimed in Claim 11 in which said first and second objects are layers intended to be brought into aligned superposed relation.

13. A method as claimed in Claim 12 in which said first and second objects are associated with first and second colour planes in the printing of an image.

14. A method as claimed in Claim 12 in which said first and second objects are respective colour plane negatives used in the process of burning printing plates for colour printing.

15. A method as claimed in Claim 12 in which said first object is a semiconductor substrate and the second object is a mask for use therewith.

16. A method as claimed in Claim 12 in which said first and second objects are respective masks for use in formation of an integrated circuit on a substrate.

17. A method as claimed in any one of Claims 11 to 14 in which the displacement of the bright spot from the centre of the register marks is measured as an indication of the amount and direction of misalignment of the marks, and said relative movement is effected in accordance with said measurement.

18. A method as claimed in Claim 17 in which the measurement of the displacement comprises the steps of:

capturing an image of the interference pattern in a memory,
determining the position of peak of the bright spot,
calculating the error between the position of said peak and the centre of one of the register marks,
ascertaining if the error is at a minimum and if so indicating alignment of the first and second register marks.

19. A method of monitoring the alignment of first and second objects in which said first and second objects carry first and second register marks respectively for locating in overlaid relation to determine the alignment of said first and second objects, characterized in that:

said first and second register marks provide a register mark arrangement which is in accordance with any one of Claims 1 to 10,
and the method comprises the steps of
detecting the position of the peak of said bright spot,
calculating the error between the position of said peak, and the centre of one of the register marks, and
ascertaining if the error is at a minimum to indicate alignment of said first and second register marks.

20. A method as claimed in Claim 19 in which the detection of the position of the peak of said bright spot includes capturing in memory an image of the interference pattern between said first and second register marks.

21. Apparatus for monitoring the alignment of first and second objects carrying first and second register marks respectively which register marks are located in overlaid relation, characterized in that:

said first and second register marks provide a register mark arrangement which is in accordance with any one of Claims 1 to 10, and said apparatus comprises:
detection means for detecting the position of the peak of said bright spot,
means for calculating the error between the position of said peak and the centre of one of the register marks, and
means for ascertaining if the error is at minimum to indicate alignment of said first and second register marks.

22. Apparatus for aligning first and second objects carrying first and second register marks respectively, which register

marks are located in overlaid relation, characterized in that:

said first and second register marks provide a register mark arrangement which is in accordance with any one of Claims 1 to 9, and the apparatus comprises:
detection means for detecting the position of the peak of said bright spot,
means for calculating the error between the position of said peak and the centre of one of the register marks,
means for relatively moving said first and second register marks in dependence upon said error in order to minimize said error indicative of alignment of said first and second register marks.

23. Apparatus as claimed in Claim 21 or 22 in which said detection means includes means for capturing in memory an image of the interference pattern between said first and second register marks.

24. Apparatus as claimed in Claim 21, 22, or 23 wherein said apparatus is for colour printing and said first and second objects are associated with first and second colour planes in the printing of an image.

25. Apparatus as claimed in Claim 21, 22 or 23 wherein the apparatus is for the production of printing plates for colour printing and said first and second objects are respective colour plane negatives for use in the process of burning respective printing plates.

26. Apparatus as claimed in Claim 21, 22 or 23 wherein the apparatus is for the production of integrated circuits and said first object is a semiconductor substrate and the second object is a mask for use therewith.

27. Apparatus as claimed in Claim 21, 22 or 23 wherein the apparatus is for the production of integrated circuits and said first and second objects are respective masks for use in the formation of an integrated circuit on a substrate.

Patentansprüche

1. Ausrichtmarkenanordnung mit:

einer ersten Ausrichtmarke (10), die eine erste Mehrzahl von Elementen aufweist, deren räumliche Anordnungshäufigkeit über die erste Ausrichtmarke (10) variiert, und
einer zweiten Ausrichtmarke (12), die eine zweite Mehrzahl von Elementen aufweist, deren räumliche Anordnungshäufigkiet über die zweite Ausrichtmarke (12) variiert,

dadurch gekennzeichnet,

daß die Elemente der ersten und der zweiten Mehrzahl von Elementen Punkte sind,
daß sich die räumliche Häufigkeit jeder ersten und zweiten Mehrzahl von Punkten in derselben Richtung mit zunehmender Entfernung von der Mitte der ersten bzw. der zweiten Ausrichtmarke verändert,
daß die räumliche Häufigkeit der Punkte der zweiten Ausrichtmarke größer ist als die räumliche Häufigkeit der Punkte der ersten Ausrichtmarke in entsprechenden Bereichen der ersten und der zweiten Ausrichtmarke, und
daß die erste und die zweite Mehrzahl von Punkten derart angeordnet und die räumlichen Häufigkeiten derart gewählt sich, daß ein Interferenzmuster erzeugt wird, das einen hellen Fleck in der Mitte der Ausrichtmarken aufweist, wenn die Ausrichtmarken in übereinander liegender Beziehung angeordnet sind, wobei dies die Ausfluchtung der ersten und der zweiten Ausrichtmarke anzeigt.

2. Ausrichtmarkenanordnung nach Anspruch 1,
wobei die erste und die zweite Mehrzahl von Punkten jeweils mindestens eine Reihe von Punkten in je einer von zwei orthogonalen Richtungen aufweisen.

3. Ausrichtmarkenanordnung nach Anspruch 1,
wobei jede erste und zweite Mehrzahl von Punkten eine zweidimensionale Anordnung von Punkten ist, wobei die räumliche Häufigkeit der Punkte in entgegengesetzten Richtungen von der Mitte der jeweiligen ersten und zweiten Ausrichtmarke abnitmmt.

4. Ausrichtmarkenanordnung nach Anspruch 1,

wobei jede erste und zweite Mehrzahl von Punkten eine zweidimensionale Anordnung von Punkten ist, wobei die räumliche Häufigkeit der Punkte in entgegengesetzten Richtungen von der Mitte der jeweiligen ersten und zweiten Ausrichtmarke zunimmt.

5. Ausrichtmarkenanordnung nach Anspruch 1,
wobei jede erste und zweite Mehrzahl von Punkten eine zweidimensionale Anordnung von Punkten ist, wobei die räumliche Häufigkeit der Punkte eine Funktion der radialen Distanz von der Mitte der Ausrichtmarke ist.

6. Ausrichtmarkenanordnung nach Anspruch 5,
wobei bei jeder ersten und zweiten Mehrzahl von Punkten die räumliche Häufigkeit mit zunehmender radialer Distanz von der Mitte der ersten bzw. zweiten Ausrichtmarke abnimmt.

7. Ausrichtmarkenanordnung nach Anspruch 5,
wobei bei jeder ersten und zweiten Mehrzahl von Punkten die räumliche Häufigkeit mit zunehmender radialer Distanz von der Mitte der ersten bzw. zweiten Ausrichtmarke zunimmt.

8. Ausrichtmarkenanordnung nach einem der vorausgehenden Ansprüche,
wobei die räumliche Häufigkeit der Punkte der zweiten Mehrzahl etwa 5 % höher ist als die räumliche Häufigkeit der Punkte der ersten Mehrzahl in entsprechenden Bereichen der ersten und der zweiten Ausrichtmarke.

9. Ausrichtmarkenanordnung nach einem der Ansprüche 1 bis 8,
wobei die erste Ausrichtmarke aufgedruckt ist und die zweite Ausrichtmarke auf diese projiziert wird.

10. Ausrichtmarkenanordnung nach einem der vorausgehenden Ansprüche,
wobei die erste Ausrichtmarke aufgedruckt ist und die zweite Ausrichtmarke darüber aufgedruckt ist.

11. Verfahren zum Ausfluchten eines ersten und eines zweiten Gegenstands, wobei der erste und der zweite Gegenstand eine erste bzw. eine zweite Ausrichtmarke zur Anordnung in übereinander liegender Beziehung aufweisen, um die Ausfluchtung des ersten und des zweiten Gegenstands festzustellen,
dadurch gekennzeichnet,

daß die erste und die zweite Ausrichtmarke eine Ausrichtmarkenanordnung bilden, die gemäß einem der Ansprüche 1 bis 9 ausgebildet ist, und
daß eine Relativbewegung zwischen dem ersten und dem zweiten Gegenstand hervorgerufen wird, um das Interferenzmuster zwischen der ersten und der zweiten Ausrichtmarke in einen Zustand zu bringen, in dem ein heller Fleck in der Mitte der Ausrichtmarken gebildet wird, der das Ausfluchten derselben anzeigt.

12. Verfahren nach Anspruch 11,
wobei der erste und der zweite Gegenstand Schichten sind, die in ausgefluchtete übereinander angeordnete Beziehung gebracht werden sollen.

13. Verfahren nach Anspruch 12,
wobei der erste und der zweite Gegenstand einer ersten und einer zweiten Farbebene beim Drucken eines Bildes zugeordnet werden.

14. Verfahren nach Anspruch 12,
wobei der erste und der zweite Gegenstand jeweilige Farbebenen-Negative sind, die bei dem Vorgang des Brennens von Druckplatten für den Farbdruck verwendet werden.

15. Verfahren nach Anspruch 12,
wobei der erste Gegenstand ein Halbleitersubstrat ist und der zweite Gegenstand eine Maske zur Verwendung mit diesem ist.

16. Verfahren nach Anspruch 12,
wobei der erste und der zweite Gegenstand jeweilige Masken zur Verwendung bei der Bildung einer integrierten Schaltung auf einem Substrat sind.

17. Verfahren nach einem der Ansprüche 11 bis 14,

wobei die Verlagerung des hellen Flecks von der Mitte der Ausrichtmarken als Anzeige für den Betrag und die Richtung der Fehlausfluchtung der Marken gemessen wird und die Relativbewegung nach Maßgabe der Messung hervorgerufen wird.

18. Verfahren nach Anspruch 17,

wobei die Messung der Verlagerung folgende Schritte umfaßt:
Festhalten eines Bilds des Interferenzmusters in einem Speicher,
Bestimmen der Position des Maximums des hellen Flecks,
Berechnen des Fehlers zwischen der Position des Maximums und der Mitte von einer der Ausrichtmarken,
Feststellen, ob der Fehler ein Minimum beträgt, und, falls dem so ist, Anzeigen von Ausfluchtung der ersten und der zweiten Ausrichtmarke.

19. Verfahren zum Überwachen der Ausfluchtung eines ersten und eines zweiten Gegenstands, wobei der erste und der zweite Gegenstand eine erste bzw. eine zweite Ausrichtmarke zur Anordnung in übereinander liegender Beziehung tragen, um die Ausfluchtung des ersten und des zweiten Gegenstands zu bestimmen, dadurch gekennzeichnet,

daß die erste und die zweite Ausrichtmarke eine Ausrichtmarkenanordnung bilden, die nach einem der Ansprüche 1 bis 10 ausgebildet ist,
und daß das Verfahren folgende Schritte aufweist:
Feststellen der Position des Maximums des hellen Flecks,
Berechnen des Fehlers zwischen der Position des Maximums und der Mitte von einer der Ausrichtmarken, und
Festellen, ob der Fehler ein Minimum beträgt, und, falls dem so ist, Anzeigen von Ausfluchtung der ersten und der zweiten Ausrichtmarke.

20. Verfahen nach Anspruch 19,
wobei die Feststellung der Position des Maximums des hellen Flecks ein Festhalten eines Bilds des Interferenzmusters zwischen der ersten und der zweiten Ausrichtmarke in einem Speicher beinhaltet.

21. Vorrichtung zum Überwachen der Ausfluchtung eines ersten und eines zweiten Gegenstands, die eine erste bzw. eine zweite Ausrichtmarke tragen, wobei die Ausrichtmarken sich in übereinander liegender Beziehung befinden, dadurch gekennzeichnet,

daß die erste und die zweite Ausrichtmarke eine Ausrichtmarkenanordnung bilden, die gemäß einem der Ansprüche 1 bis 10 ausgebildet ist, und
daß die Vorrichtung folgendes aufweist:
eine Erfassungseinrichtung zum Erfassen der Position des Maximums des hellen Flecks,
eine Einrichtung zum Berechnen des Fehlers zwischen der Position des Maximums und der Mitte von einer der Ausrichtmarken,
eine Einrichtung zum Feststellen, ob der Fehler ein Minimum beträgt, um eine Ausfluchtung der ersten und der zweiten Ausrichtmarke anzuzeigen.

22. Vorrichtung zum Ausfluchten eines ersten und eines zweiten Gegenstands, die eine erste bzw. eine zweite Ausrichtmarke tragen, wobei die Ausrichtmarken sich in übereinander liegender Beziehung befinden,
dadurch gekennzeichnet,

daß die erste und die zweite Ausrichtmarke eine Ausrichtmarkenanordnung bilden, die gemäß einem der Ansprüche 1 bis 9 ausgebildet ist, und
daß die Vorrichtung folgendes aufweist:
eine Erfassungseinrichtung zum Erfassen der Position des Maximums des hellen Flecks,
eine Einrichtung zum Berechnen des Fehlers zwischen der Position des Maximums und der Mitte von einer der Ausrichtmarken,
eine Einrichtung zum relativen Bewegen der ersten und der zweiten Ausrichtmarke in Abhängigkeit von dem Fehler, um den Fehler auf ein Minimum zu reduzieren, der ein Ausfluchten der ersten und der zweiten Ausrichtmarke anzeigt.

23. Vorrichtung nach Anspruch 21 oder 22,

wobei die Erfassungseinrichtung eine Einrichtung zum Festhalten eines Bilds des Interferenzmusters zwischen der ersten und der zweiten Ausrichtmarke in einem Speicher beinhaltet.

24. Vorrichtung nach Anspruch 21, 22 oder 23,
wobei die Vorriohtung zum Farbdrucken dient und der erste und der zweite Gegenstand einer ersten und einer zweiten Farbebene beim Drucken eines Bildes zugeordnet sind.

25. Vorrichtung nach Anspruch 21, 22 oder 23,
wobei die Vorrichtung zur Herstellung von Druckplatten für das Farbdrucken dient und der erste und der zweite Gegenstand jeweilige Farbebenen-Negative zur Verwendung bei dem Vorgang des Brennens der jeweiligen Druckplatten sind.

26. Vorrichtung nach Anspruch 21, 22 oder 23,
wobei die Vorrichtung zur Herstellung integrierter Schaltungen dient und der erste Gegenstand ein Halbleitersubstrat ist und der zweite Gegenstand eine Maske zur Verwendung mit diesem ist.

27. Vorrichtung nach Anspruch 21, 22 oder 23,
wobei die Vorrichtung zur Herstellung integrierter Schaltungen dient und der erste und der zweite Gegenstand jeweilige Masken zur Verwendung bei der Bildung einer integrierten Schaltung auf einem Substrat sind.

Revendications

1. Agencement de marques d'alignement comportant :

une première marque d'alignement (10) incluant une première pluralité d'éléments, dont la fréquence de l'agencement spatial varie à travers la première marque d'alignement (10), et
une seconde marque d'alignement (12) incluant une seconde pluralité d'éléments, dont la fréquence de l'agencement spatial varie à travers la seconde marque d'alignement (12),

caractérisé en ce que :

les éléments desdites première et seconde pluralités d'éléments comprennent des points,
la fréquence spatiale de chacune desdites première et seconde pluralités de points varie dans le même sens avec la distance à partir du centre desdites première et seconde marques d'alignement, respectivement,
la fréquence spatiale des points de ladite seconde marque d'alignement est supérieure à la fréquence spatiale des points de ladite première marque d'alignement au niveau de zones correspondantes des première et seconde marques d'alignement, et
lesdites première et seconde pluralités de points étant agencées et lesdites fréquences spatiales étant choisies de manière à produire une figure d'interférence incluant une tache claire au niveau du centre desdites marques d'alignement, lorsque lesdites marques d'alignement sont superposées, qui est indicative de l'alignement desdites première et seconde marques d'alignement.

2. Agencement de marques d'alignement selon la revendication 1, dans lequel lesdites première et seconde pluralités de points comprennent chacune au moins une ligne de points dans chacune de deux directions orthogonales.

3. Agencement de marques d'alignement selon la revendication 1, dans lequel chacune desdites première et seconde pluralités de points est un réseau bidimensionnel de points, où la fréquence spatiale des points diminue dans des directions opposées à partir du centre des première et seconde marques d'alignement respectives.

4. Agencement de marques d'alignement selon la revendication 1, dans lequel chacune desdites première et seconde pluralités de points est un réseau bidimensionnel de points, où la fréquence spatiale des points augmente dans des directions opposées à partir du centre des première et seconde marques d'alignement respectives.

5. Agencement de marques d'alignement selon la revendication 1, dans lequel chacune desdites première et seconde pluralités de points est un réseau bidimensionnel de points, où la fréquence spatiale des points est une fonction de la distance radiale à partir du centre de la marque d'alignement.

6. Agencement de marques d'alignement selon la revendication 5, dans lequel, dans chacune desdites première et seconde pluralités de points, la fréquence spatiale diminue avec la distance radiale à partir du centre des première et seconde marques d'alignement, respectivement.

7. Agencement de marques d'alignement selon la revendication 5, dans lequel, dans chacune desdites première et seconde pluralités de points, la fréquence spatiale augmente avec la distance radiale à partir du centre des première et seconde marques d'alignement, respectivement.

8. Agencement de marques d'alignement selon l'une quelconque des revendications précédentes, dans lequel la fréquence spatiale des points de ladite seconde pluralité est de l'ordre de 5 % supérieure à la fréquence spatiale des points de ladite première pluralité au niveau de zones correspondantes desdites première et seconde marques d'alignement.

9. Agencement de marques d'alignement selon l'une quelconque des revendications 1 à 8, dans lequel ladite première marque d'alignement est imprimée et ladite seconde marque d'alignement est projetée sur celle-ci.

10. Agencement de marques d'alignement selon l'une quelconque des revendications précédentes, dans lequel ladite première marque d'alignement est imprimée et ladite seconde marque d'alignement est imprimée sur celle-ci.

11. Procédé pour aligner des premier et second objets, dans lequel lesdits premier et second objets portent des première et seconde marques d'alignement, respectivement, destinées à être superposées afin de déterminer l'alignement desdits premier et second objets, caractérisé en ce que :

lesdites première et seconde marques d'alignement constituent un agencement de marques d'alignement qui est défini selon l'une quelconque des revendications 1 à 9, et dans lequel un déplacement relatif est effectué entre lesdits premier et second objets afin d'amener la figure d'interférence entre lesdites première et seconde marques d'alignement dans un état dans lequel ladite tache claire apparaît au centre des marques d'alignement, indicatif de leur alignement.

12. Procédé selon la revendication 11, dans lequel lesdits premier et second objets sont des couches destinées à être superposées en étant alignées.

13. Procédé selon la revendication 12, dans lequel lesdits premier et second objets sont associés à des premier et second plans de couleur dans l'impression d'une image.

14. Procédé selon la revendication 12, dans lequel lesdits premier et second objets sont les négatifs des plans de couleur respectifs utilisés au cours du processus de réalisation de planches à imprimer pour l'impression en couleur.

15. Procédé selon la revendication 12, dans lequel ledit premier objet est un substrat semi-conducteur et le second objet est un masque destiné à être utilisé avec celui-ci.

16. Procédé selon la revendication 12, dans lequel lesdits premier et second objets sont des masques respectifs, destinés à être utilisés dans la formation d'un circuit intégré sur un substrat.

17. Procédé selon l'une quelconque des revendications 11 à 14, dans lequel le déplacement de la tache claire à partir du centre des marques d'alignement est mesuré comme indication de l'écart d'alignement des marques et de la direction de ce mauvais alignement, et ledit déplacement relatif est effectué conformément à ladite mesure.

18. Procédé selon la revendication 17, dans lequel la mesure du déplacement comporte les étapes consistant à :

procéder à l'acquisition d'une image de la figure d'interférence dans une mémoire,
déterminer la position du maximum d'intensité de la tache claire,
calculer l'erreur entre la position dudit maximum d'intensité et le centre de l'une des marques d'alignement,
vérifier si l'erreur est à un minimum et, si tel est le cas, indiquer l'alignement des première et seconde marques d'alignement.

19. Procédé pour vérifier l'alignement de premier et second objets, dans lequel lesdits premier et second objets portent des première et seconde marques d'alignement, respectivement, destinées à être superposées afin de déterminer

l'alignement des premier et second objets, caractérisé en ce que :

lesdites première et seconde marques d'alignement constituent un agencement de marques d'alignement qui est défini selon l'une quelconque des revendications 1 à 10,
et le procédé comporte les étapes consistant à
détecter la position du maximum d'intensité de ladite tache claire,
calculer l'erreur entre la position dudit maximum d'intensité et le centre de l'une des marques d'alignement, et vérifier si l'erreur est à un minimum afin d'indiquer l'alignement desdites première et seconde marques d'alignement.

20. Procédé selon la revendication 19, dans lequel la détection de la position du maximum d'intensité de ladite tache claire comporte l'acquisition en mémoire d'une image de la figure d'interférence entre lesdites première et seconde marques d'alignement.

21. Dispositif pour surveiller l'alignement de premier et second objets portant des première et seconde marques d'alignement, respectivement, lesquelles marques d'alignement sont superposées, caractérisé en ce que :

lesdites première et seconde marques d'alignement constituent un agencement de marques d'alignement qui est défini selon l'une quelconque des revendications 1 à 10, et ledit dispositif comporte :
des moyens de détection pour détecter la position du maximum d'intensité de ladite tache claire,
des moyens pour calculer l'erreur entre la position dudit maximum d'intensité et le centre de l'une des marques d'alignement, et
des moyens pour vérifier si l'erreur est à un minimum afin d'indiquer l'alignement desdites première et seconde marques d'alignement.

22. Dispositif pour aligner des premier et second objets portant des première et seconde marques d'alignement, respectivement, lesquelles marques d'alignement sont superposées, caractérisé en ce que :

lesdites première et seconde marques d'alignement constituent un agencement de marques d'alignement qui est défini selon l'une quelconque des revendications 1 à 9, et le dispositif comporte :
des moyens de détection pour détecter la position du maximum d'intensité de ladite tache claire,
des moyens pour calculer l'erreur entre la position dudit maximum d'intensité et le centre de l'une des marques d'alignement,
des moyens pour déplacer d'une manière relative lesdites première et seconde marques d'alignement en fonction de ladite erreur afin de minimiser ladite erreur indicative de l'alignement desdites première et seconde marques d'alignement.

23. Dispositif selon la revendication 21 ou 22, dans lequel lesdits moyens de détection comportent des moyens pour acquérir en mémoire une image de la figure d'interférence entre lesdites première et seconde marques d'alignement.

24. Dispositif selon la revendication 21, 22 ou 23, dans lequel le dispositif est destiné à l'impression en couleur et lesdits premier et second objets sont associés à des premier et second plans de couleur dans l'impression d'une image.

25. Dispositif selon la revendication 21, 22 ou 23, dans lequel le dispositif est destiné à la production de planches à imprimer pour l'impression en couleur et lesdits premier et second objets sont les négatifs des plans de couleur respectifs destinés à être utilisés au cours du processus de réalisation des planches à imprimer respectives.

26. Dispositif selon la revendication 21, 22 ou 23, dans lequel le dispositif est destiné à la production de circuits intégrés et ledit premier objet est un substrat semi-conducteur et le second objet est un masque destiné à être utilisé avec celui-ci.

27. Dispositif selon la revendication 21, 22 ou 23, dans lequel le dispositif est destiné à la production de circuits intégrés et lesdits premier et second objets sont des masques respectifs destinés à être utilisés dans la formation d'un circuit intégré sur un substrat.

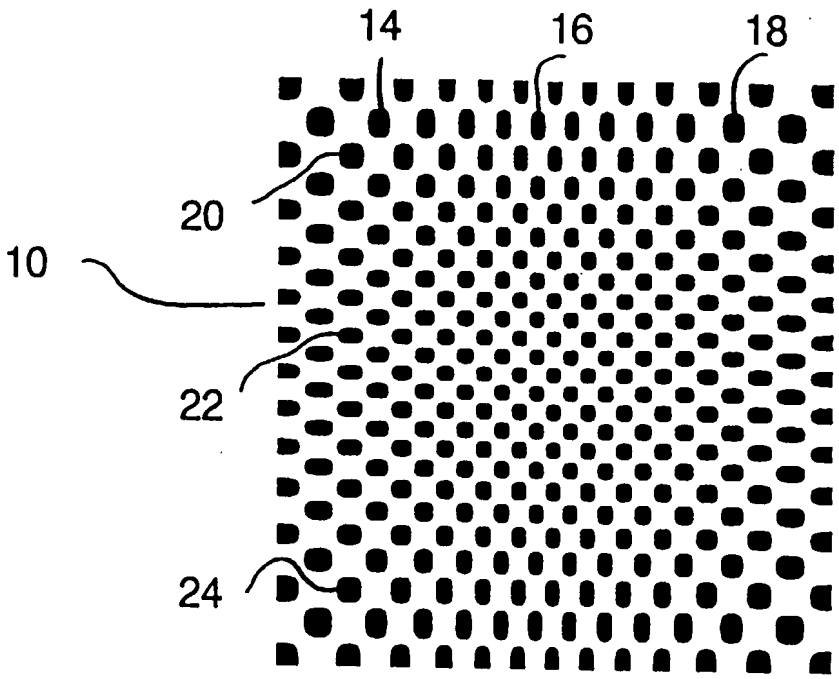

Fig. 1

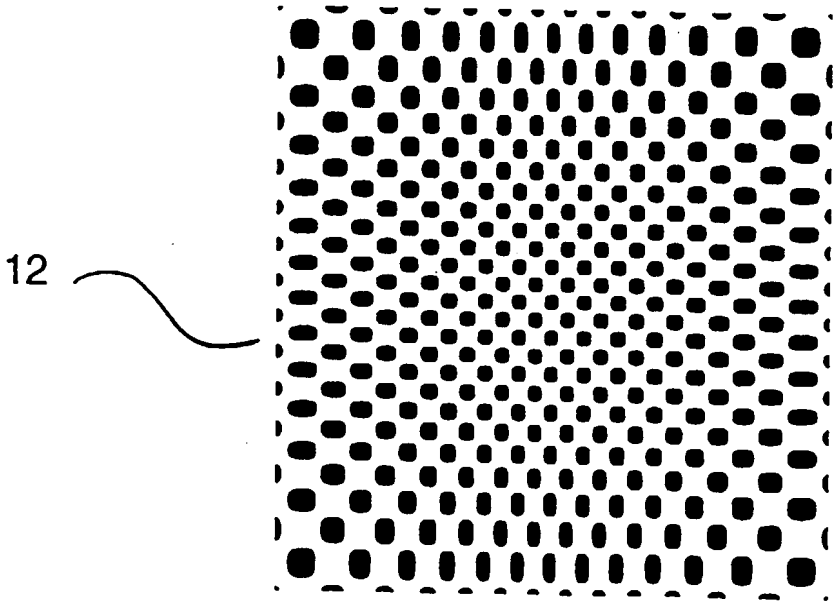

Fig. 2

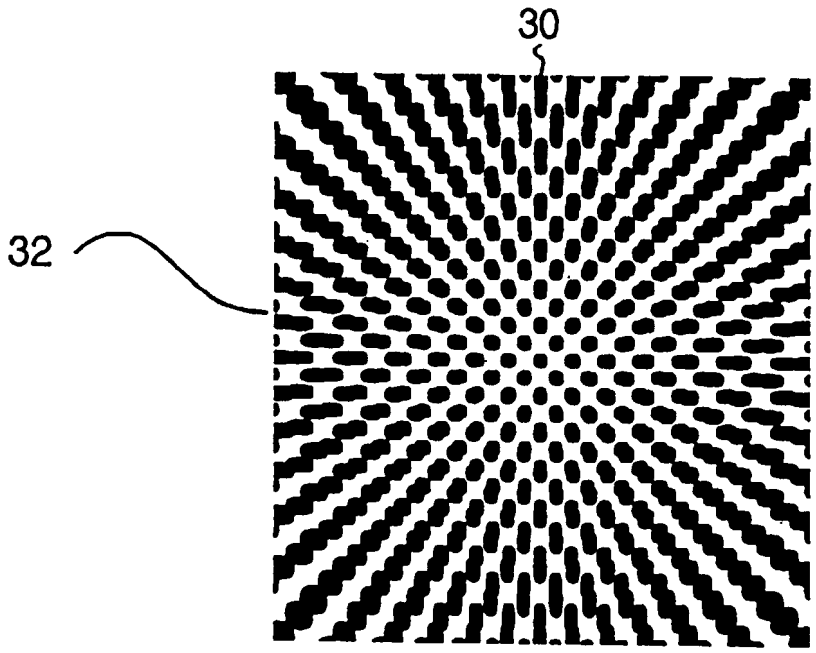

Fig. 3

IN REGISTER

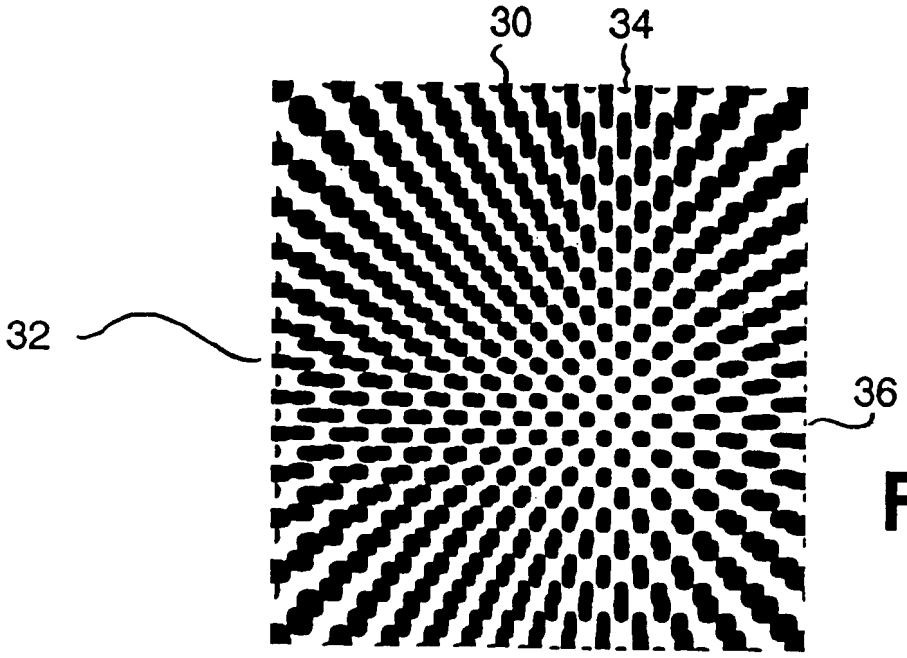

Fig. 4

OUT OF REGISTER
3 PIXELS RIGHT, 2 PIXELS DOWN

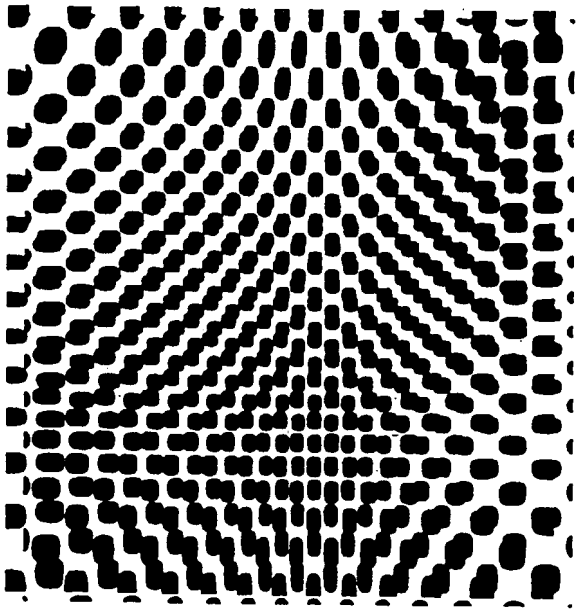

Fig. 5

OUT OF REGISTER
13 PIXELS RIGHT, 5 PIXELS DOWN

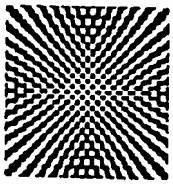

Fig. 6A
IN REGISTER

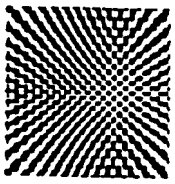

Fig. 6B
+2 PIXELS

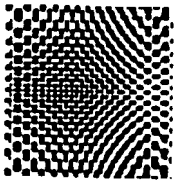

Fig. 6C
+4 PIXELS

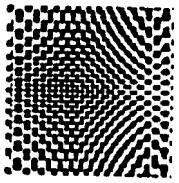

Fig. 6D
+6 PIXELS

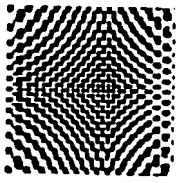

Fig. 6E
+8 PIXELS

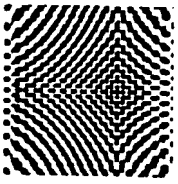

Fig. 6F
+10 PIXELS

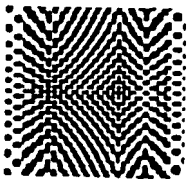

Fig. 6G
+12 PIXELS

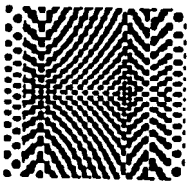

Fig. 6H
+14 PIXELS

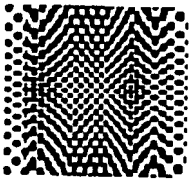

Fig. 6I
+16 PIXELS

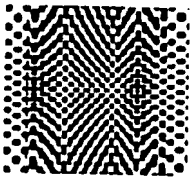

Fig. 6J
+18 PIXELS

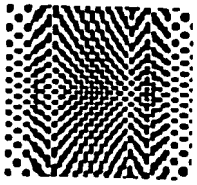

Fig. 6K
+20 PIXELS

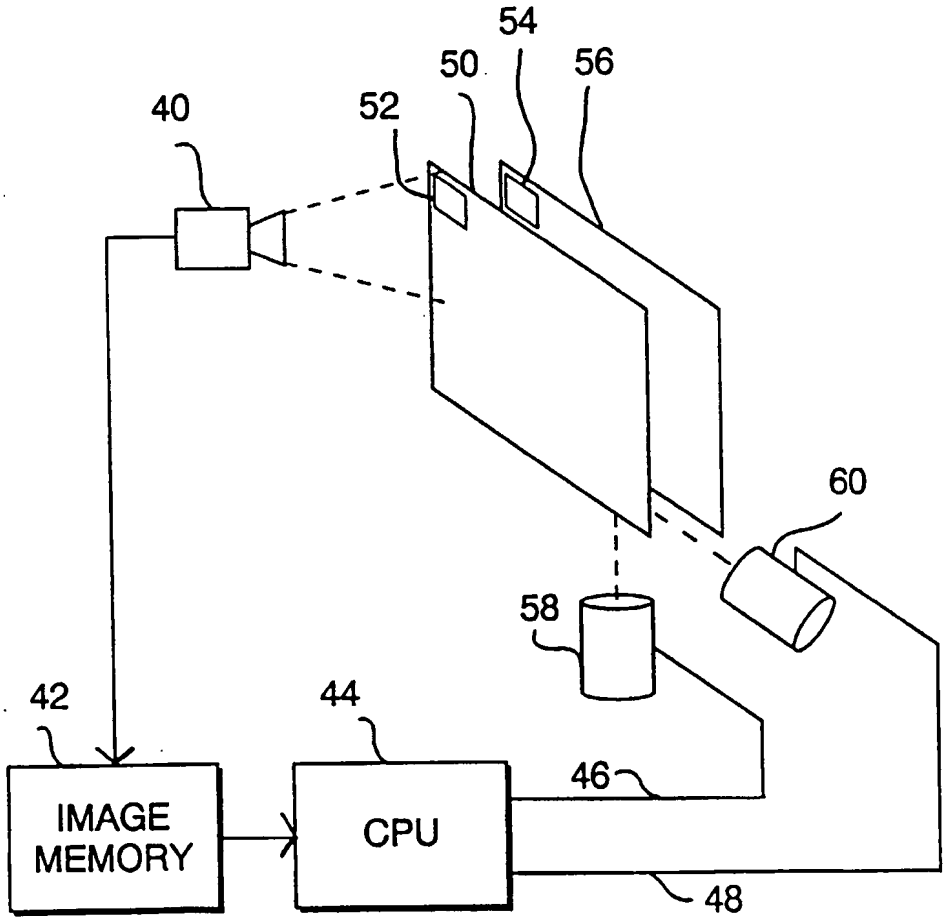

Fig. 7

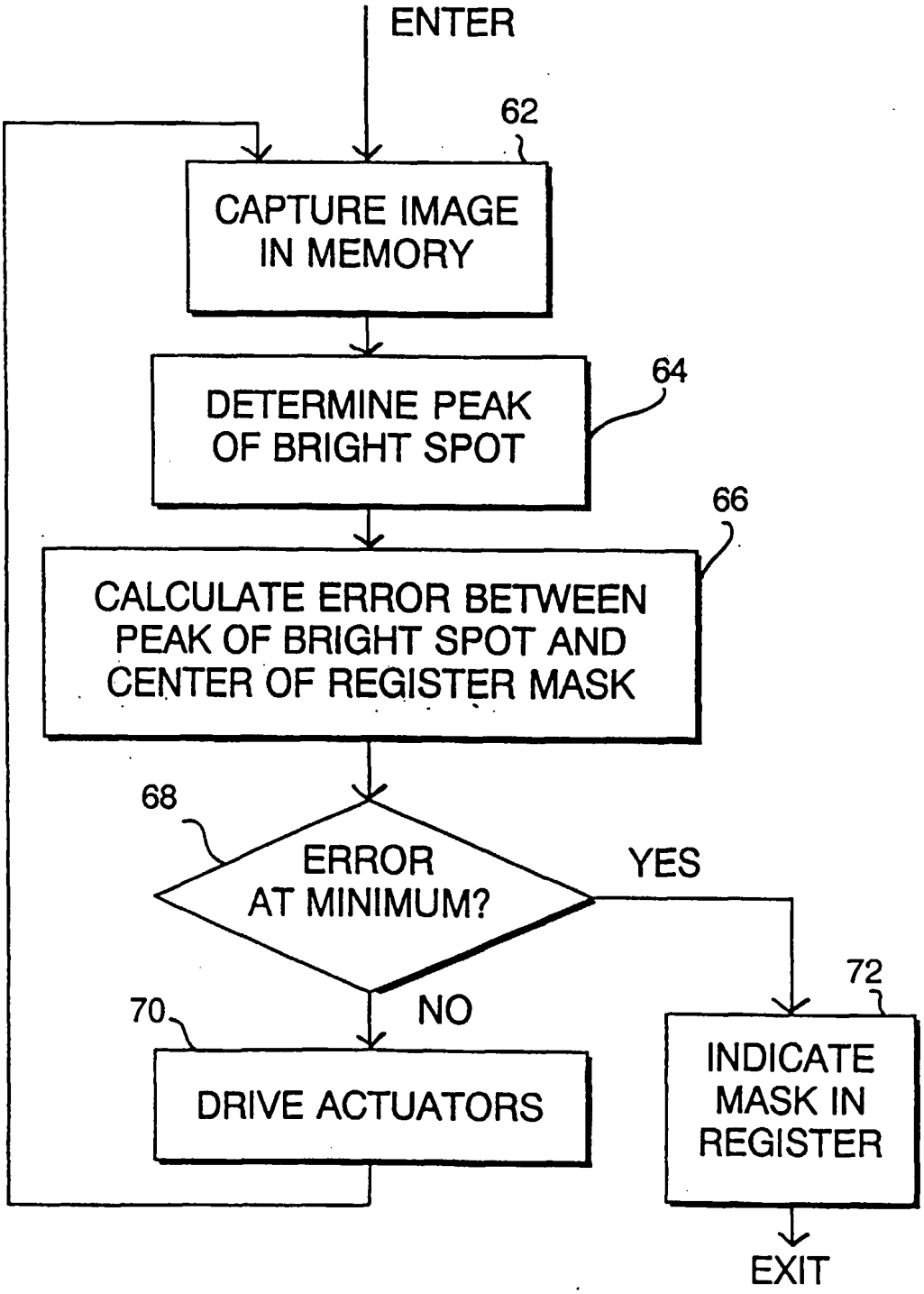
ENTER
62
CAPTURE IMAGE IN MEMORY
64
DETERMINE PEAK OF BRIGHT SPOT
66
CALCULATE ERROR BETWEEN PEAK OF BRIGHT SPOT AND CENTER OF REGISTER MASK
68
ERROR AT MINIMUM?
YES
NO
70
DRIVE ACTUATORS
72
INDICATE MASK IN REGISTER
EXIT

Fig. 8